DE 199 17 330 A1

Microreactor module

Abstract

A microreactor module (100) with reactor elements, such as fluid ducts, reaction chambers, heating devices, mixing devices and the like, is provided, for the formation of a microsystem consisting of a number of microreactor modules (100) of identical and different type, with connection elements (120, 122) which, when in each case second microreactor modules (100) are connected, connect positively to one another in such a way that fluid ducts leading from one module to the other are connected to one another so as to be sealed off relative to the outside.

Description

The invention relates to a microreactor module with reactor elements, such as fluid ducts, reaction chambers, heating devices, mixing devices and the like, a number of microreactor modules of identical and different type being capable of being assembled to form a microreactor system interconnected via fluid ducts.

Systems of this type may be used, for example, for individual operations, such as the execution of chemical, biochemical and physico-chemical reactions, distillation, mixing, separation, etc., or else for setting up an entire chain of operations amounting to a miniaturized chemical factory.

EP-A-0 688 242 discloses a chemical microreactor which consists of a number of thin structured plates lying one above the other. The plates are connected to one another. The microreactor may comprise a whole number of operation units, such as mixers, distributors, heat exchangers, separators and reaction chambers, and be provided with sensors, valves, pumps and the like. Although a plurality of these known microreactors can also be arranged in parallel or in series, the microreactor nevertheless constitutes, above all, a completer reaction unit for an entire process.

The recent trend, on the other hand, has been to assemble modules of relatively simple construction on the building block principle to form reactors for the desired process. The individual building blocks of the modular microsystem constructed in this way must in this case be connected to one another mechanically, fluidically, optically, thermally, and, if ppropriate,

also electrically conductively at interfaces. So that individual building blocks can be exchanged, the connections should be releasable.

Releasable connections, such as plug connections, screw connections and the like, are, admittedly, known in many sectors of technology. In general, in this case, the parts to be connected are led towards one another in the axial direction, aligned with one another and pressed together and held together by means of force-exerting parts. Hitherto, however, the releasable connection of microreactor modules in microsystems has received little attention.

The object of the invention is to design the microreactor modules mentioned in the introduction in such a way that a connection of the microreactor modules is possible in one or more dimensions. Preferably, the connection is to be releasable again.

This object is achieved, according to the invention, by means of the arrangement mentioned in Patent Claim 1. Advantageous refinements of the arrangement according to the invention are defined in the subclaims.

The microreactor module according to the invention, which comprises reactor elements, such as fluid ducts, reaction chambers, heating or cooling devices, mixing or separating devices, optical and electrical elements and the like, can be assembled to form a microsystem. For this purpose, it is provided with a connection system with connection elements which, when at least two microreactor modules are assembled to form a system, connect positively to one another in such a way that the fluid ducts leading from one module to the other are connected to one another so as to be sealed off relative to the

outside.

In an embodiment according to the invention, the connection elements are designed as male and female elements. A laterally transposed interconnection of the modules can thereby be prevented. In many instances, however, it may be desirable to connect a module to other modules both in one direction of flow and in the opposite direction of flow, as required. In such instances, the connection element is designed to be of neutral sex.

It has proved particularly expedient to connect the modules to one another by means of a tension element which exerts on the modules a connecting force pressing these onto one another. These tension elements may act as separate elements on the modules from outside. However, they may expediently also be arranged in the connection element itself.

Preferably, the connection elements are hook-shaped or dovetail-shaped elements which are arranged on the microreactor modules and which engage one into the other with play, in such a way that a relative movement of the microreactor modules perpendicularly to the connecting axis is possible by means of a spacing between the microreactors, in which case the play between the two microreactor modules can be cancelled by means of tension elements which can be inserted into an orifice formed by clearances in the connection elements. The connection elements may either be connected to the module in one piece or else be attached to the module by means of screws or a similar element or else by means of welding and the like. Alternatively, the connection elements may consist of grooves in the microreactor modules, in each case two microreactor modules being connected by means of profile pieces which can be inserted into

the cavity formed by two grooves located opposite one another.

The connection system according to the invention for microreactor modules has the advantage that individual modules can be removed from the system, without the entire set-up being dismantled. In the case of a rectangular or cubic configuration of the microreactor module, the necessary connections of electrical, fluidic technology and other type are possible in all 6 spatial directions. In principle, however, other configurations are also possible.

Reactor modules of this type may contain all the operation elements necessary for setting up a chemical plant, such as, for example, reaction spaces which, where appropriate, can be heated or else cooled and in which the substances to be reacted come into contact with one another under vigorous agitation, and also small agitators or pumps, distillation elements, microscopically small separation gels, centrifuges, for example also fluidically acting spiral centrifuges, or else light sources, such as, for example, light-guiding glass fibres. Such modules may also contain elements for the control, regulation, detection and monitoring of processes. Plants for producing the most diverse possible substances can thereby be assembled. Since, in such plants, in each case only extremely small quantities are reacted, it is possible, for example, for the heating, cooling or separation of the substances to take place in fractions of a second. The modular reactors are consequently suitable both for mixing, heating, cooling, electrically induced operations and operations induced optically by light, for example also for measurement and monitoring of reactions by means of optical detectors, for centrifuging and filtration and for the modification

of physical and chemical states of substances. This is also the case, in particular, due to the fact that long paths between the individual process steps are dispensed with, since the individual reactors lie directly next to one another.

By means of arrangements of this type, constructed from microreactors, it is possible to control chemical reactions accurately, so that, for example, they take place under control in kinetic and/or thermodynamic terms. This results in entirely novel reaction techniques which have hitherto not been accessible in chemical synthesis. By a multiplicity of such microreactor plants being connected in parallel, it is possible, by means of these, to carry out reactions with substances on a large scale, that is to say in the region of several tons per year.

The microreactor module according to the invention can easily be combined with what may be referred to as a fluid conductor board, the fluidic equivalent of the electrical circuit board in electrical engineering. In a particular embodiment according to the invention, the microreactor modules are designed for use with fluid conductor boards. In this case, the fluid conductor board has corresponding connection elements fitting the reactor module. The fluid conductor board itself has conductor elements, by means of which the reactor modules can be provided with reaction fluids, cooling or heating fluids or else mechanical elements or electrical current or voltage. They may also contain optical conduction elements, such as, for example, glass fibres. In a further refinement according to the invention, the fluid conductor board is designed in such a way that the reactor modules are not or not solely arranged in direct contact with one another,

but also communicate with one another via the lines arranged in the fluid conductor boards.

Embodiments of the invention are explained in more detail below with reference to the drawing in which:

Fig. 1 shows a perspective view of a microreactor module;

Fig. 2(a) to 2(d) show possibilities for the arrangement of a number of microreactor modules;

Fig. 3(a) and 3(b) show a microreactor module with connection elements;

Fig. 4(a) and 4(b) show diagrammatically the connection of two microreactor modules by means of connection elements according to Fig. 3;

Fig. 5(a) to 5(e) show tension elements for the connection according to Fig. 4;

Fig. 6(a) and 6(b) and Fig. 7(a) and 7(b) show further alternative tension elements for the connection according to Fig. 4;

Fig. 8(a) to 8(c) show a variant of the connection of two microreactor modules; and

Fig. 9(a) and 9(b) show two further variants for the connection of two microreactor modules.

Fig. 1 of the drawing shows a microreactor module 10 in the form of a cube, which is provided for a microsystem constructed from a large number of such modules having partially different functions. The modules may in each case be closed-off functional units for entire processes or functional units for part-processes, such as mixing, heating, cooling, centrifuging or filtration for electrooptical operations or detections or else for changing the physical or chemical state. Other modules, in turn, may contain only fluid ducts or signal lines or be only closing-off modules which, for example, close off fluid lines or lead out of the system.

The cube form shown is not absolutely necessary for the microreactor modules; the modules may, for example, also have a rectangular form.

The microreactor module 10 may, in the simplest instance, be produced in one piece, but it is preferably assembled from at least 2 parts 11 which, in particular, are connected releasably to one another. In at least one part, the structures necessary for the respective function of the module are formed, for example fluid ducts, cavities for reaction chambers and the like. In the embodiment shown, the parts 11 are screwed to one another by means of screws 12. The parts may, however, also be connected to one another in any other way.

Some of the lateral surfaces of the microreactor module 10 have fluid-duct orifices 14, 16, via which fluids are supplied to the module 10 from outside or via which fluids are discharged outwards from the module 10. The orifice 14 is surrounded by an annular groove 17 which receives an elastic sealing element, such as an O-ring or the like. The orifice 16 is not surrounded by such an annular groove. The sealing element (not shown) in the annular groove 17 is compressed when another second module is arranged on the lateral surface of the first module 10 having the orifice 14 and is pressed down in such a way that the lateral surfaces of the two modules bear against one another. If the second module has a fluid-duct orifice 16, without surrounding annular groove, opposite the orifice 14 in the first module 10, this results in a fluid connection between the modules which is sealed off relative to the outside.

Furthermore, sockets 18 for electrical connections, optical inspection windows for the monitoring of reactions and/or also accesses for the

introduction or extraction of substances, for example also of catalysts and the like, may be provided in one (or else a plurality) of the lateral surfaces of the microreactor module 10. A system may also have modules with straightforward connection and junction functions with measuring and regulating technology, with actuators, pumps and/or valves.

The microsystem is constructed from a number of such and similar modules which may be arranged one-dimensionally (linearly), two-dimensionally (in one plane) and three-dimensionally (spatially). The modules may in this case be held together by the individual modules being screwed to one another, by screw connections by means of continuous screws or by being screwed or clamped into fixed forms. Fig. 2(a) to 2(c) show some such arrangements. In the arrangement of Fig. 2(a), the microreactor modules 10, which are located in a frame 60, are pressed together by means of screws 62 which act on clamping wedges 64. Fig. 2(b) illustrates an arrangement in which the microreactor modules 10 are pressed into the frame 60 by means of a toggle-lever device 66, and Fig. 2(c) illustrates an arrangement in which this takes place by means of an eccentric device 68. Finally, Fig. 2(d) shows a top view of a microsystem arranged in two dimensions and consisting of a number of microreactor modules 10, which is held together by means of tension screws 70. With regard to bracing in the second (or third) dimension, it is necessary, basically, to ensure that individual cubes are not pressed transversely out of the linearly braced module rows. This may take place, for example, by means of supporting cubes which serve only for mechanical support and which prevent tilting. Furthermore, other module cubes which contain specific or reaction-assisting elements may also be arranged.

It is also possible to have clamping connections between the modules on flanges via clamping parts, such as, for example, ring clips, and snap connections with plug elements latching one in the other.

However, such screw, clamping and plug connections are not particularly flexible in terms of set-up, and, for example in order to exchange a module, a complete demounting of the entire system is necessary, even in the case of a linear arrangement.

In order to avoid this, there is therefore provision for providing the microreactor module with connection elements. The first embodiment, shown in Fig. 3(a), of a microreactor module 100 has a connection system with hook-shaped connection elements 120, 122 on the microreactor module 100. The connection elements 120, 122 may be produced integrally or in one piece with the microreactor module 100. They may, however, also be screwed on, glued on, welded or the like. The connection element 122 is attached on that side of the microreactor module 100 which is located opposite the side having the connection element 120 and is formed complementarily to the connection element 120.

Fig. 3(b) shows a preferred embodiment of the connection of Fig. 3(a), in which the hook-shaped connection elements 120a, 120b have recesses 121a, 121b and corner clearances 124a and 124b. In this special embodiment, the corner clearances 124a, 124b are arranged in such a way that they have an internal thread for screwing in a screw, the internal threads for the adjacent connection elements 120a and 120b being arranged in such a way that the screws can be screwed in as tension elements 128 from opposite sides.

For a multi-dimensional connection of microreactor modules 100, further connection elements 120, 122 may be provided on the other opposite sides of the microreactor module 100.

Like the microreactor module 10, the microreactor module 100 consists of parts 111 which are held together by screws 112. In the side walls of the microreactor module 100 are located fluid-duct orifices 114 and 116 with or without a surrounding annular groove 117.

The first connection element 120 of the microreactor module 100 consists of two parts which are arranged at a distance from one another and point towards one another and which are undercut in a hook-shaped or L-shaped manner, and the second connection element 122 consists of a part undercut in a T-shaped manner. During the assembly of two modules 100, the T-shaped connection element 122 is pushed behind the two hook-shaped parts of the first connection element 120 by means of a relative movement of the two modules parallel to those side walls of the modules on which the connection elements 120, 122 are located, until the two modules lie exactly opposite one another and possible fluid-duct orifices 114 and 116 are aligned exactly with one another. This alignment may be facilitated by means of stops (not shown) on the connection elements 120, 122.

As shown in Fig. 4(a) and 4(b), the connection set up from the two connection elements 120, 122 has a marked play, so that the two connection elements 120, 122 for the two modules to be connected can be pushed one into the other, whilst the modules themselves are held at a sufficient spacing 130, so that, during assembly, the seal in the annular groove 117 around the fluid-duct orifice 114 at a fluid duct

115 is not damaged by being sheared off (Fig. 4(a)).

In order, as shown in Fig. 4(b), to bring the spacing 130 between the two modules 100 to be connected to zero and connect the fluid ducts 115 so as to be sealed off relative to the outside, the connection elements 120, 122 have on their insides clearances 124, 126 (cf. Fig. 3) which run parallel to those side walls of the modules 100 which bear against one another, and which, when two modules are assembled, lie opposite one another.

When the fluid-duct orifices 114, 116 and the modules 100 are aligned with one another, tension elements 128 are introduced into the clearances 124, 126, the said tension elements cancelling the play between the two modules 100 and applying the sealing force necessary for the sealing-off of fluid.

The tension elements 128 may be designed differently. Fig. 5(a) shows a cylindrical tension element 128, and Fig. 5(b) shows a conical tension element 128 in the form of corresponding pins or wedges which are knocked into the essentially cylindrical orifice formed by the clearances 124, 126, the cylindrical tension element 128 preferably being provided with a tip for easier introduction. As shown in Fig. 5(c), if appropriate, conically configured screws may also be used as the tension element 128. In a particularly preferred embodiment, the tension element 128 has a cylindrical clearance with an internal thread. This makes it possible to screw a pulling device (not illustrated), provided with a corresponding counterthread, into the tension element 128 and consequently pull out the latter from the clearances 124, 126 in the connection elements 120, 122 in the manner of a corkscrew. Finally, it is possible, as shown in Fig. 5(d) and 5(c), to

introduce into the orifice formed by the clearances 124, 126 an eccentric element which, for example, has an oval cross-sectional form and which is rotated about its longitudinal axis in order to pull the two modules 100 together (cf. Fig. 5(c)).

Fig. 6(a) and 6(b) show tension elements 128 in the form of screws which press or pull a wedge (Fig. 6(a)) or two wedges (Fig. 6(b)) into the orifice formed by the clearances 124, 126.

As shown in Fig. 7(a) and 7(b), sleeves slotted in a dowel-like manner may also be used as the tension elements 128. The tension element 128 of Fig. 7(a) consists of a sleeve which is slotted at the end and is provided with a conical internal thread and into which a screw is screwed. Such a sleeve can be manufactured easily in that, first, solid material is slotted, into which an internal thread is subsequently cut. In this case, the sleeve expands, so that a conical internal thread is obtained. During the assembly of modules 100, the sleeves are plugged into cylindrical clearances 124, 126 and the screws are then screwed into the sleeves.

Fig. 7(b) shows a variant in which the sleeve of the tension element 128 is, for example, slotted four times centrally. When the associated screw is screwed in, the sleeve then expands correspondingly in the middle.

Fig. 8 shows a connection system for the microreactor modules 100, in which the connection elements 140, 142 for the sliding connection are configured or undercut in a dovetail-shaped manner (Fig. 8(a)). The orifice formed by clearances 144, 146 in the connection elements 140, 142 can then have inserted into it, as described above, a tension

element 128 adapted to it, for example an eccentric tension element 128, which is rotated in order to tension the two modules 100 together (Fig. 8(b), Fig. 8(c)).

In an alternative embodiment, the connection system is designed in such a way that the rectangular or cubic housing geometry of the microreactor modules 100 is essentially preserved. For this purpose, grooves 150 having an undercut are formed in the side walls of the microreactor modules 100, that is to say in the cubic or rectangular body of the modules 100. Two of the grooves 150 are preferably provided in each side wall.

In a first variant shown in Fig. 9(a), the groove 150 in each of the side walls of the microreactor module 100 has a T-form. When two modules 100 are laid against one another, the grooves 150 are located opposite one, and a cavity having a double-T form is obtained. The two modules 100 are connected by means of a profile piece 152 which is inserted into the cavity and the cross section of which corresponds to the cross section of the cavity formed from the two grooves 150 located opposite. One end of the profile piece 152 may be shaped conically for easier introduction.

In another variant, the grooves 150 are dovetail-shaped, so that, when two modules 100 are assembled, a double dovetail is obtained, into which a profile piece 152 of corresponding cross section is inserted.

The microreactor modules described preferably have a standard grid dimension, for example a grid dimension of 25 mm, which is in relatively widespread use in building block systems. The material for the

microreactor modules is selected, as required, for example plastic, steel, high-grade steel or else coated material or a composite material.

The microreactor modules described can be combined with fluid conductor boards. Fluid conductor boards are fluidically technically equivalent to the known circuit boards for electrical circuits, and the microreactor modules in this case correspond to the components applied to the circuit boards for defined functions in the circuit. The microreactors on the fluid conductor boards can thus ensure defined conditions in specific process steps, for example exact temperature and mixing conditions and the like. By reactants being combined, specific reactions can also be brought about in a controlled manner in the microreactors, the products of these reactions then being led further on again in the fluid conductor board. Furthermore, fluid conductor boards may be used in order, for example, to feed uniformly a plurality of parallel microreactor process lines. In a similar way, the products from such a plant can be collected via a fluid conductor board.

So that they can fulfil their function, the microreactor modules must be connected mechanically and fluidically to the fluid conductor board. This may take place via direct connections between the modules and the conductor board or via separate lines. There is also the possibility of using connecting modules which lead ducts in the conductor board further on to specific reactor modules.

List of reference symbols

10 Microreactor module
11 Parts
12 Screws
14, 16 Fluid-duct orifices
17 Annular groove
18 Socket
60 Frame
62 Screws
64 Clamping wedges
66 Toggle-lever device
68 Eccentric device
70 Tension screws
100 Microreactor module
111 Parts
112 Screws
114 Fluid-duct orifice
115 Fluid duct
116 Fluid-duct orifice
117 Annular groove
120, 122 connection elements
121 Recess
128 Tension elements
130 Spacing
140, 142 Connection elements
150 Grooves
152 Profile piece

Patent Claims

1. Microreactor module (100) with reactor elements, such as fluid ducts (115), reaction chambers, heating devices, mixing devices and the like, a number of microreactor modules (100) of identical and different type being capable of being assembled to form a microreactor system interconnected via fluid ducts, characterized by a connection system with connection elements (120, 122; 140, 142; 150, 152) which, when at least two microreactor modules (100) are assembled to form a reactor system, connect these positively to one another in such a way that fluid ducts (115) leading from one module to the other are connected to one another so as to be sealed off relative to the outside.

2. Microreactor module according to Claim 1, characterized in that the connection elements are designed as male/female elements.

3. Microreactor module according to Claim 1, characterized in that the connection elements are of neutral sex.

4. Microreactor module according to one of the preceding claims, characterized in that the connection elements engage one into the other.

5. Microreactor module according to one of the preceding claims, characterized in that the microreactor system has tension elements for connecting the modules.

6. Microreactor module according to one of the preceding claims, characterized in that the connection elements (120, 122; 140, 142) are hook-shaped or dovetail-shaped elements which are arranged on the microreactor modules (100) and which engage

one into the other with play, in such a way that a relative movement of the microreactor modules (100) perpendicularly to the axis of fluid ducts (115) to be connected is possible by means of a spacing (130) between the microreactors, in which case the play between the microreactor modules (100) can be cancelled by means of tension elements (128) which can be inserted into an orifice formed by clearances (124, 126; 144, 146) in the connection elements (120, 122; 140, 142).

7. Microreactor module according to one of the preceding claims, characterized in that the tension elements (128) comprise cylindrical pins, conical screws, conical wedges, slotted sleeves, screws, snap fastenings and/or eccentric elements.

8. Microreactor module according to one of the preceding claims, characterized in that the tension elements (128) have an internal thread.

9. Microreactor module according to one of the preceding claims, characterized in that the connection elements comprise grooves (150) in the microreactor modules (100), in each case two microreactor modules (100) being connected by means of profile pieces (152) which can be inserted into the cavity formed by two grooves (150) located opposite one another.

10. Microreactor module according to Claim 9, characterized in that the grooves (150) are T-shaped, and in that the profile pieces (152) have correspondingly a double-T form.

11. Microreactor module according to Claim 9, characterized in that the grooves (150) are dovetail-shaped, and the profile pieces (152) are correspondingly double-dovetail-shaped.

12. Microreactor module according to Claim 11, characterized in that the profile pieces have a narrowed end facilitating introduction.

13. Microreactor module according to one of the preceding claims, characterized by the connection of one or more microreactor modules to a fluid conductor board.

14. Microreactor module according to Claim 13, characterized in that the fluid conductor board contains fluidic or electrical conductor elements, optical conductor elements, mechanical elements or heating and/or cooling elements.

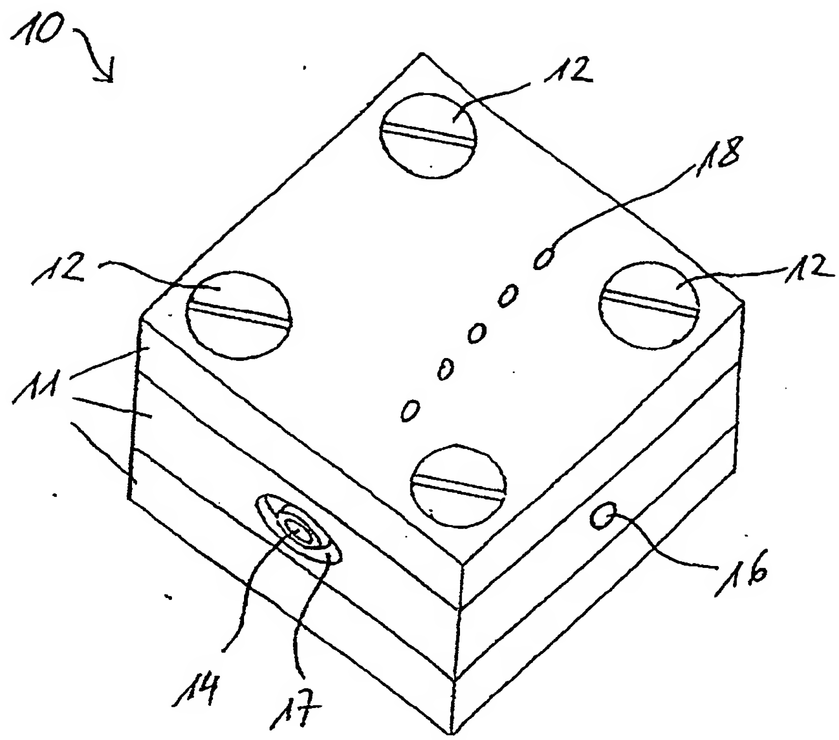

Fig. 1

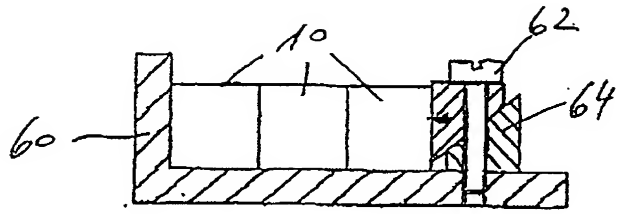

Fig. 2(a)

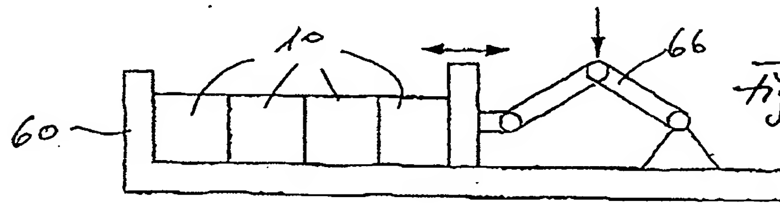

Fig. 2(b)

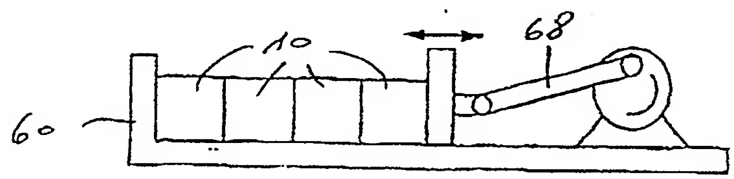

Fig. 2(c)

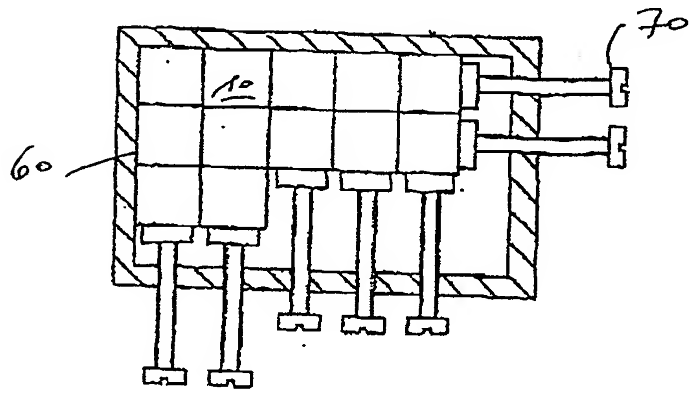

Fig. 2(d)

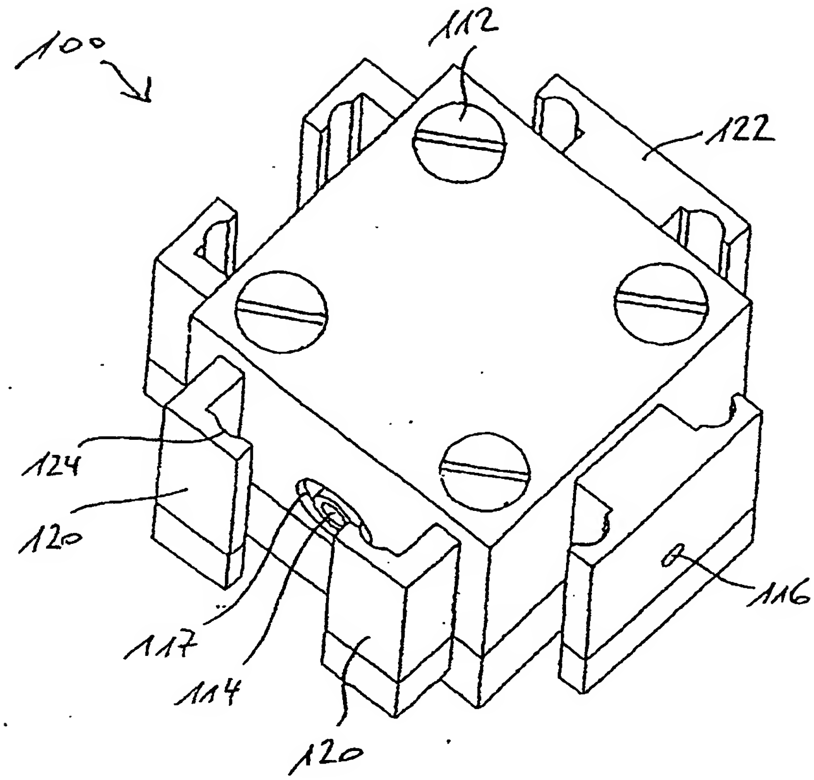

Fig. 3a

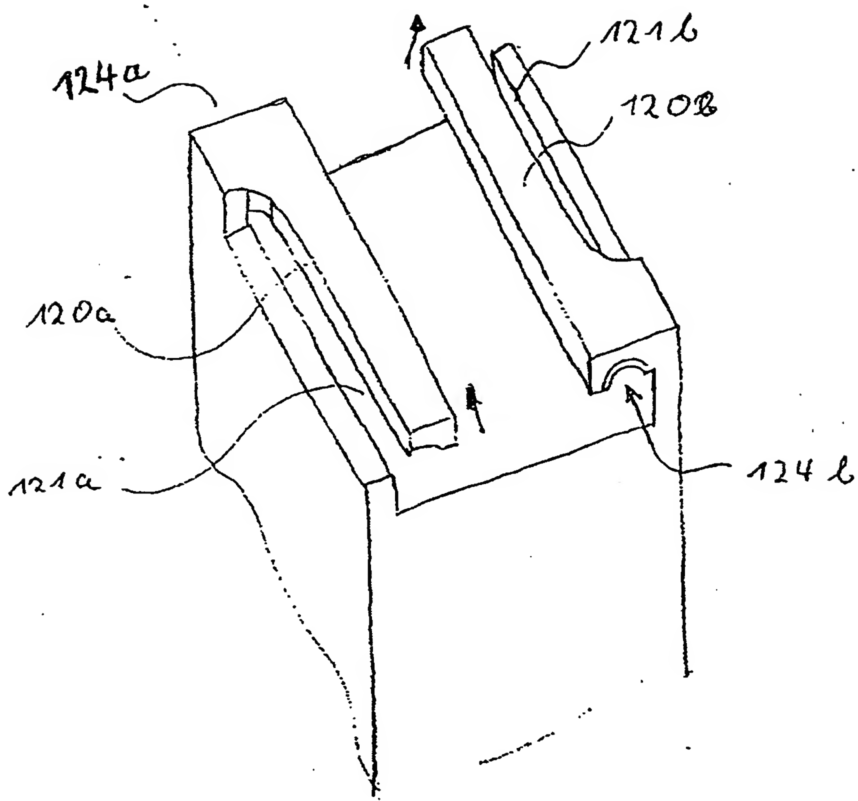

Fig. 3b

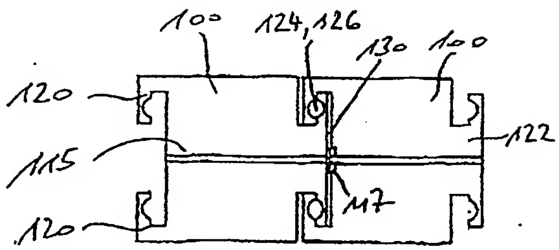

Fig. 4(a)

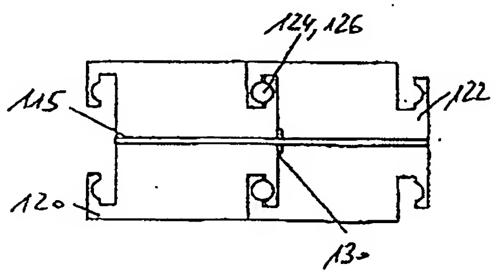

Fig. 4(b)

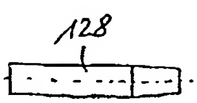

Fig. 5(a)

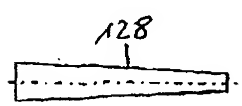

Fig. 5(b)

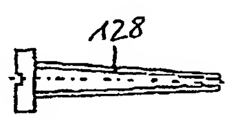

Fig. 5(c)

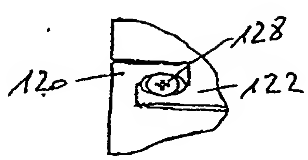

Fig. 5(d)

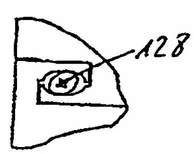

Fig. 5(e)

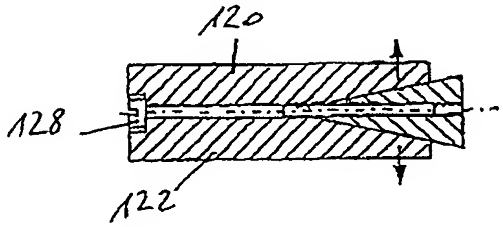

Fig. 6(a)

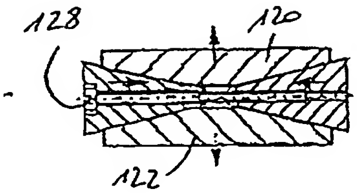

Fig. 6(b)

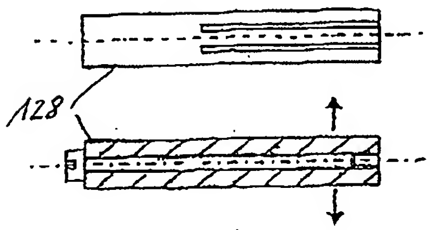

Fig. 7(a)

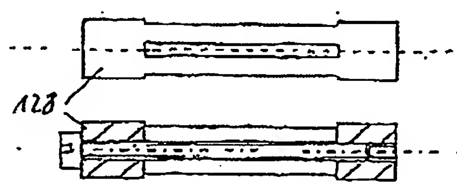

Fig. 7(b)

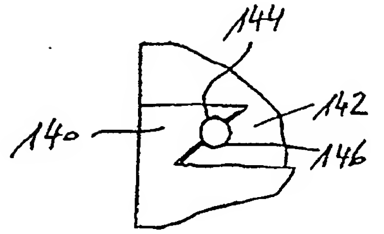

Fig. 8(a)

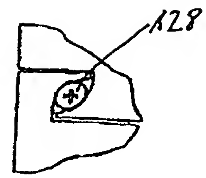

Fig. 8(b)

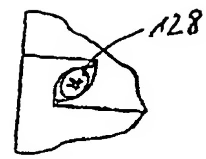

Fig. 8(c)

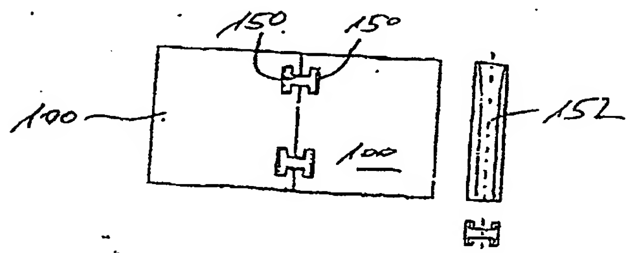

Fig. 9(a)

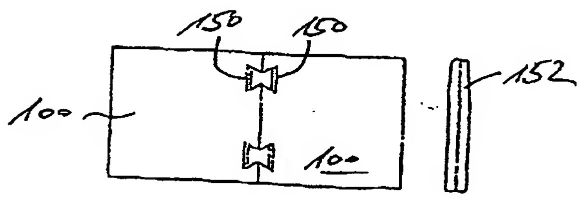

Fig. 9(b)